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Proposed Arch Bridge on Lower Lake of Bhopal : A Case Study

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ABSTRACT : In this paper the dynamic characteristic of steel tube (ST) arch bridge is studied. The finite element analysis software is 2000 is used to set up a three-dimensional finite element model of the ST arch bridge. The natural period and mode shapes of the ST arch bridge are calculated by using the complete quadratic coefficient (COC) method. The bridge is analyzed for the road bridge. The response spectrum analysis method is used as per IRC. The calculating result shows that the vertical stiffness of the arch bridge is stronger whereas the arch bridge lateral stiffness is comparably weaker in earthquake. The solution of this problem is to increase lateral stiffness of arch bridge by using alternative arrangement of cross cables.

KEYWORDS: String arch bridge, road bridge, analysis (Dynamic analysis), Mode shapes steel tube (ST), Composite structure.

INTRODUCTION

Ancient time bridges are built with stone, timber and brick masonry. The use of reinforced concrete, modern structural steel, prestressed concrete and recently developed composite sections (CFST) give the opportunity for construction and development of long span arch bridges under seismic effects. In long span bridges the natural vibration response of the arch bridge plays an important role in the seismic design of arch bridge, which may include natural frequencies of vibration and vibration mode shape of arch bridges in structural dynamic analysis. For longer span bridges the lateral direction vibration is more and hence the arch rib is required stiffer, stronger and durable which satisfied by the steel tube (ST) circular sections. The ST composite section provides more stiffness in earthquake because of the composite action in between steel tube. The proposed arch bridge on lower lake is an example developing the arch bridge in Bhopal.

In structure the steel tube (ST) circular section increasingly popular in structural application. This is due to their excellent earthquake resisting property such as high strength, high ductility and large energy dissipation capacity. As a result of combined effect of the rolled steel tube and the core concrete. ST structure can effectively take advantages of these two material to improve the compressive strength and the ductility of the structure for earthquake. The ST structure is being widely used in high rise building projects, viaduct and bridges in Japan. brazil and several other countries. The advantages of ST structure is:

i) High load carrying capacity.
ii) High ductility.
iii) Saving in formwork.
iv) Better cost performance.
v) Delay local buckling of steel tube.
vi) Identical strength and stiffness in both X and Y directions of sections.

In this paper the dynamic analysis of ST bow string arch bridge is carried out by using response spectrum method. The finite element software is used to set up a three dimensional finite element model of the ST arch bridge. The natural period and mode shape of the ST bow string arch bridge is calculated by using the complete quadratic coefficient (CQC) method. The arch bridge is analyzed for two lane bridge. The results show that the transverse direction stiffness is less for satisfying the deflection check. Hence the alternative arrangement of cross cable is proposed in this paper. The various parameters such as bending moment, shear force, axial force and stiffness of the arch rib is compared for the bridges. The bridge is located in zone II and the response reduction factor is for arch bridges.

CITY PROFILE

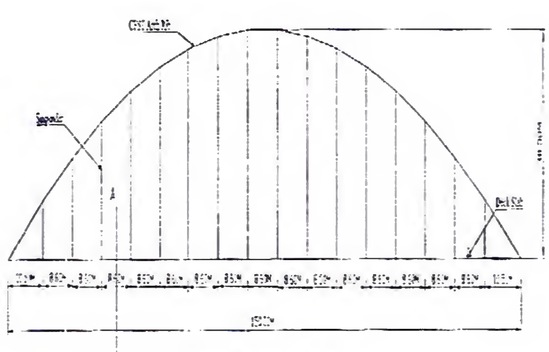
the environmental excellence is connected with the origion of the Bhopal city. It is said to have been founded by the Parmar King Bhoj during the year 1000-1055. The city was originally known as Bhojpal named after Bhoj and the dam ('pal') that is said to have been constructed by him to form the lakes surrounding the city. He created the Upper Lake by constructing an earthen dam across the Kolans River. According to the States Reorganization Act of 1956, Bhopal state was integrated into the state of Madhya Pradesh, and Bhopal was declared as its capital.

Bhopal has an average elevation of 499 meters (1637 ft) from MSL & is located in the central part of India, in the upper limit of the Vindhya Mountain ranges. The city has uneven elevation and has small hills within its boundaries. The major hills in Bhopal comprise of Idgah hills and Shyamala hills in the northern region and Arera hills in the central region. The Municipal boundaries covers 298 square kilometer, however, the develoopment area is around 285 sq. km. It has two very beautiful big lakes, collectively known as the Bhoj Wetland. These lakes are the Upper Lake and the Lower Lake locally known as the Bada Talab and Chota Talab respectively. The catchment area of the Upper Lake is 361 km^2 while that of the Lower Lake is 9.6 km^2.

The City enjoys a moderate & humid subtropical climate with mild, dry winters, a hot summer and a humid monsoon season. Summers start in late March and ends till mid-June, the average temperature being around 30 ^{0}C (86 ^{0}F), with the peak of summer in May, when the maximum exceed 40 ^{0}C (104 ^{0}F). The monsoon starts in late June and ends in late September. About 40 inches (1020 mm) of precipitation is seen in these months with frequent thunderstorms and flooding. Total annual rainfall is about 1146 mm (46 inches) falling predominantly during July and August with the average 40 rainy days in a year. The average temperature is around 25^{0}C (77 ^{0}F) and the humidity is quite high. The winter peaks in January when temperatures drops close to freezing point on some nights.

BOW-STRING ARCH BRIDGE

The ST bow string arch bridge is two line bridge. The bridges consist of twin parallel arches with a 150m span and 10.2m clear width. The shape of the arch bridge is parabolic and the rise to span ratio of arch bridge is 1:5. The arch rib is made from ST circular section. The diameter of steel tube used in ST section is 1000mm and thickness is 20mm and diameter 960mm. The unit weight of concrete is 25 KN/m^3 and unit weight of steel is 78 KN/m^3. The deck is suspended from the two arches by means of 32 no. of suspenders. The first set and last set of suspender is located at a distance of 10500mm from end there after the hanger is spaced at 8600mm c/c. The suspender of 100/125 mm diameter HD bar is used for supporting the deck. The Live load is considered for two lane Bridge. The self weight of rails, stringer, and sleepers are included in the analysis. The arch bridge deck system consists of four horizontal tied girder, end cross girder, middle cross girder and concrete deck slab. The horizontal tied girder bears not only the horizontal thrust generated by arch ribs but also vertical loads brought over by the transverse beams. In order to increase the lateral stability of the arch bridge, cross bracings are located between two parallel arch ribs. The support conditions of arch bridge are treated as one end hinged and other end is roller support. The schematic arrangement of bow string arch bridge. The proposed alternative arrangement of cross cable in bow string arch bridge.



Elevation of Bow string arch bridge

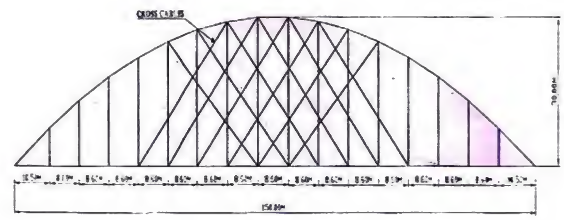


Fig 2: Model 2 of arch bridge

FINITE ELEMENT MODELING

The main bridge consists of arches, suspender and the deck which includes main girder, cross girder and deck slab. The suspenders are the components bearing tension only. In the finite element modeling the arch rib, suspender, main girder, cross girder and bracing are simulated by using three-dimensional beam element whereas the deck slab is simulated by the shell element. There are totally 2928 nodes, 1384 beam element and 2700 shell element. In order to simplify the calculation, the actual parabolic curve is discredited into several straight lines so as to adopt beam element to simulate the arches during the establishment of the finite element model of arch ribs. The mateiral constants are elastic modulus of steel Es = 2.1 x 10^5 N/mm^2 & for M40 grade concrete EC = 31622.78 N/mm^2 The density of concrete is 25 kN/m^3 and density of steel is 78 kN/m^3. The mode number are set as 8, for zone II zone factor is 0.24, Importance factor I = 1.5, Response reduction factor R = 4 and Sa/g graph is taken from IS code for the calculation of response spectrum analysis.

RESULTS AND DISCUSSION

Natural Frequency and Mode Shape

The natural frequency of the model 1 and model 2 is shown in Table 1. The ST arch bridge vibration mainly involves three types of vibration arch rib vibration in plane, vertical vibration of the whole bridge and torsion vibration. The width of arch bridge is comparably smaller and hence natural fundamental frequencies in transverse direction are obviously less than natural fundamental frequencies in longitudinal direction, which related to the stiffness in longitudinal and transverse direction. The various vibration mode shapes of the ST arch bridge and the natural frequencies of arch bridge shows that the deflection of the arch rib in longitudinal direction and in vertical direction are in safer side while the transverse direction stiffness is excessive than the permissible limits. The alternative arrangement of cross cables is provide more stiffness to the arch rib in transverse direction. The set up of cross cable provide more natural frequencies and hence in transverse direction stiffness is 30% more.

Bending Moment and Shear Force

The maximum bending moment, shear force and axial force developed in the bow string arch rib are calculated. The bending moment, shear force and axial forces of ST bow string arch bridge at end and L/4 mode is less.

CONCLUSIONS

A three-dimensional finite element model is established by using software program for ST bow string arch bridge and its dynamic behavior is analyzed. The result shows that the longitudinal and vertical stiffness of ST bow string arch bridge is more while the transverse direction stiffness is less. The bending moments are increased at the ends and L/4 node while the central moment is more. The results show that the alternative arrangement of cross cable is more stiffness.

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